

# **Hazard Class/Division 1.6: Articles Containing Extremely Insensitive Detonating Substances\***

prepared by

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## **ABSTRACT**

A brief history of Class/Division 1.5/1.6 is presented. The protocol which has been developed and approved by the United Nations for testing these materials is presented. The results of testing to determine if certain substances are Extremely Insensitive Detonating Substances (EIDS) is presented.

## **BACKGROUND**

This paper is excerpted from a longer study<sup>1</sup> performed by the author for the Department of Defense Explosives Safety Board (DDESB). This paper also contains comments and insights taken from a paper prepared by Dr. J. Ward<sup>2</sup>, of the DDESB.

The interest in less sensitive military explosives and ammunition within the Department of Defense (DOD) and the Department of Energy (DOE) dates back to the late 1970's. Since that time, these materials have been called by a variety of names. These include UN Class/Division (C/D) 1.5, DOD Insensitive High Explosives (IHE), and UN C/D 1.6. Also in the same time period, the test protocol and the corresponding pass/fail criteria for inclusion into this special group has changed as the transition has been made from the US DOD to the international (UN) arena.

In its 1977 revision of its document on the Transport of Dangerous Goods<sup>3</sup> the United Nations Group of Experts on Explosives defined "very insensitive explosives" and limited them to Type B and E blasting agents (as defined in Reference 1). In June 1979, the Air Force requested the DDESB concurrence/approval for a Department of Transportation (DOT) hazard classification of 1.5L for TATB (Triaminotrinitrobenzene) and various TATB formulations. This represented the first instance of the UN Class 1.5 designation being sought for a DOD/DOE explosive.

Shortly thereafter, the DDESB raised several technical questions regarding the application of the 1.5 classification to military materials. In order to resolve these questions, they proposed the following solution:

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\*This work was sponsored by the Department of Defense Explosives Safety Board under Military Interdepartmental Purchase Requests E8789L036 and E8790L215.

Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE <b>AUG 1990</b>		2. REPORT TYPE		3. DATES COVERED <b>00-00-1990 to 00-00-1990</b>	
4. TITLE AND SUBTITLE <b>Hazard Class/Division 1.6: Articles Containing Extremely Insensitive Detonating Substances</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Naval Surface Warfare Center,10901 New Hampshire Avenue,Silver Spring,MD,20903-5000</b>				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release; distribution unlimited</b>					
13. SUPPLEMENTARY NOTES <b>See also ADA235005, Volume 1. Minutes of the Explosives Safety Seminar (24th) Held in St. Louis, MO on 28-30 August 1990.</b>					
14. ABSTRACT <b>see report</b>					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>Same as Report (SAR)</b>	18. NUMBER OF PAGES <b>17</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			

...It is suggested that the objective development of criteria for hazard division 1.5 could best be accomplished by a tri-Service working group with recognized expertise in evaluating explosive properties, such as the Joint Technical Coordinating Group for Munitions Development Working Party for Explosives, in cooperation with Service safety office representatives.

The DDESB further requested that the Joint Technical Coordinating Group for Munitions Development: Working Party for Explosives (JTTCG/MD/WPE) <sup>4</sup>:

- (a) Review the UN Classification scheme for 1.5 materials and determine its applicability to DOD/DOE materials
- (b) Define the levels of sensitivity, response to stimuli, and effects on surroundings for division 1.5 storage/operational applications
- (c) Recommend the minimum probabilities and confidence levels to be accepted in a Division 1.5 testing scheme
- (d) Express opinions as to whether sensitivity, reaction effects, or both should be the criteria used for reducing/eliminating quantity-distance requirements.

In February 1980, the JTTCG/MD/WPE established an Ad Hoc Study Group to advise the DDESB and to determine a tri-Service position on the Hazard Classification 1.5 for explosive materials (high explosives, propellants, pyrotechnics, etc) and munitions containing these materials. The terms of reference for this group included:

- (a) Define the criteria to be used to establish the 1.5 Classification Criteria for military explosives and munitions
- (b) Study other issues arising from the introduction of the UN classification scheme, as required

The official title of the Group was the Ad Hoc Study Group on Criteria for Insensitive Explosives, Hazard Classification Division 1.5. The members of the Ad Hoc Group represented the three services and the Department of Energy. After much discussion and deliberation, the Group reached a consensus on a test protocol for Division 1.5 substances and recommended them back to the DDESB on 24 April 1980.

The Secretariat at the DDESB indicated that they supported the test procedures for classifying insensitive high explosives substances as hazard division 1.5. They further recommended that for hazard classification testing of articles (note: emphasis is theirs) containing hazard division 1.5 substances, the requirements of STANAG 4123 (Methods to Determine and Classify the Hazards of Ammunition)<sup>5</sup> and TB 700-2 (Department of Defense Explosives Hazard Classification Procedures)<sup>6</sup> should be followed. At the 279th Meeting of the Department of Defense Explosives Safety Board, the report of the Ad Hoc Study Group was accepted with minor changes. These changes included the following redefinition of Hazard Division 1.5:

This division comprises class/division 1.1 explosives substances which, although mass detonating, are so insensitive that there is negligible probability of initiation or transition from burning to detonation in transport or storage.

The DDESB, however, still desired a well-defined test protocol which could be used for articles--not just substances. On January 21, 1981 a DDESB memorandum for the three Service Board Members summarized the status of Hazard Classification for Insensitive Explosives. The following is quoted from that memorandum:

...The 279th and 281st meetings of the Board ...addressed hazard classification criteria for insensitive explosives. At the 279th meeting, the Board accepted the JTCG Ad Hoc Study Group report ... with certain changes and, in addition, established an interim hazard division 1.5 quantity-distance standard. At the 281st meeting, the Board addressed validation tests information furnished by the Ad Hoc Study Group and the Department of Energy on certain TATB formulations and comparative explosives. Included were results of tests which were not addressed ... (e.g. multiple bullet impact test). It was stated that the multiple bullet impact test can give different, sometimes more violent, results than the single bullet impact test. The question was raised, but not resolved, as to its applicability in the test scheme for evaluating Division 1.5 explosives.

On March 16, 1981, the Ad Hoc Study Group was disestablished. The WPE then convened a special meeting for the purpose of reviewing and modifying as necessary the WPE recommendations to the DDESB and to prepare a final WPE position on this matter. As a consequence of this meeting, the WPE forwarded to the DDESB a set of comments on modifications to its proposed test scheme. One of the comments is of particular importance and is quoted below:

...UN hazard classification division 1.5 was devised for commercial blasting agents which are insensitive because of large critical diameters. A separate classification 1.X (or 1. some other designation) is recommended for military explosives which have relatively small critical diameters but still are insensitive. These two types of insensitive explosives respond differently to hazard stimuli and should not be covered in one category. ... The division 1.X classification would apply and be restricted to materials passing an appropriate test scheme and criteria, and having the same physical and chemical state properties as when tested.<sup>7</sup>

During this same time period, the Air Force recommended the following tests for the Ground Launched Cruise Missile (GLCM) which it hoped to be classified as a Class/Division 1.5 article :

Impact Test (Sled Track or Pull Down)  
Bonfire  
Bullet Impact

In addition to these tests, they had run the following tests:

Forty Foot Drop  
Propagation Test  
Shaped Charge  
Thermal Stability Test

At the 283rd and 284th meetings of the DOD Explosives Safety Board (both held in January 1982), Class/Division 1.5 testing was discussed. The discussions at the 283rd meeting concerned the bullet impact test for articles, while the discussions at the 284th meeting concerned the terminology associated with Class/Division 1.5.. Quoting from the minutes of the 284th meeting;

... 1.5 has its origin in transportation circles (the UN requirements for transportation), that it applies only to substances (namely, blasting agents) and that it really adds to confusion when you start talking about articles (ammunition) in the same manner. We feel that the term insensitive high explosive, as we proposed, avoids this and achieves the objective that we were trying to achieve. This does require changing the interim criteria but only in an incidental way i.e., removing references to 1.5...<sup>8</sup>

The report of the 284th meeting provides the definitions and test protocol for IHE (Insensitive High Explosives) and IHE ammunition as they currently appear in DOD 6055.9-STD (DOD Ammunition and Explosives Safety Standards)<sup>9</sup>. The protocol, as shown in this document, consists of the following:

#### SCREENING TESTS

Impact Test  
Friction Test  
Differential Thermal Analysis (DTA)  
Small Scale Burn  
Spark Tests

#### QUALIFICATION TESTS FOR IHE

Critical Diameter	External Fire
Cap Test	SusanTest
Card Gap Test	Bullet Impact
Slow Cook-off	

## QUALIFICATION TESTS FOR IHE AMMUNITION

Sled Test  
Bonfire  
Propagation  
Slow Cook-off  
Multiple Bullet

DOD 6055.9-STD is a United States document with applicability limited to Department of Defense agencies and their contractors. In order to achieve a wider distribution and applicability, the DDESB, as technical consultant to the Department of Transportation (DOT), continued to urge its adoption by the United Nations with the protocol incorporated into the document "Recommendations on the TRANSPORT OF DANGEROUS GOODS Tests and Criteria"<sup>10</sup>. In 1983, the DDESB petitioned the Department of Transportation for the establishment of a regulation for the transport of insensitive high explosive (IHE) substances and IHE ammunition articles by or for a component of the DOD. The DDESB further proposed that the test protocol incorporated in DOD 6055.9-STD be included in Title 49, Part 149 of the Code of Federal Regulations (CFR).

In 1985, the United States agreed to make a formal proposal to the United Nations Group of Experts on Explosives; this proposal concerned the inclusion of articles in Division 1.5. In April 1986, a draft of this proposal was transmitted to the United States representative at the Department of Transportation. It was formally proposed at the twenty-sixth session of the Group of Experts on Explosives, held in August 1986. The French made detailed comments and recommended several additions and changes. The test series as modified by the French was found to be generally acceptable by the United States representative.

The revised test protocol was presented and discussed at the twenty-seventh session of the Group of Experts on Explosives, held 17-21 August 1987. As a result of the discussions at this meeting, the DDESB, in late 1987, requested that the Naval Surface Warfare Center (NSWC) review the existing protocol for Hazard Class/Division 1.5 and IHE materials. This review was to include, but was not limited to :

- (a) the coordination and the obtaining of recommendations of changes to the procedures with/from the appropriate Service hazard classification test experts
- (b) conversion of US test weight and measure specifications into the international system of units (SI)
- (c) conversion of US test materials/standard specifications to international terminology.

The DDESB position on the implementation of this test is to conduct the first without confinement (Test 7(k)) and then conduct the next two tests with confinement (UN Test 6(b)). The unconfined test permits collection of airblast and fragmentation data without the attenuating effects of confinement; the confined tests subjects the acceptors to a more severe environment. Plans are to propose this modification to the UN Group of Experts at a future date.

## TEST RESULTS

Seven explosive substances either have been or are currently being examined under the Test Series 7 protocol. These materials are:

COMPOSITION B	60% RDX, 40% TNT, 1% WAX	cast material
PBX-9502	95% TATB, 5% KEL-F	pressed material
AFX-920	22%RDX, 33%HBNQ, 15% EDDN, 14% Aluminum, 15% binder, 1% other	cast material
AFX-930	32% RDX, 37% HBNQ, 15% aluminum, 9% binder, 7% plasticizer	cast material
AFX-931	32% RDX, 37% AP, 15% aluminum, 9% binder, 7% plasticizer	cast material
B3003	80% HMX, 20% energetic binder	cast material
B3103	51% HMX, 30% energetic binder, 19% aluminum	cast material
OCTORANE 86A	86% HMX, 14% inert binder	cast material

where HBNQ is high bulk density nitroguanadine and AP is ammonium perchlorate.

The DDESB funded the testing of COMPOSITION B and PBX-9502; AFX-920, AFX-930, and AFX-931 were developed and tested under Air Force contract. B3003, B3103, and OCTORANE 86A are French explosives tested by SNPE. The US conducted the Susan test on the three French materials, while the French performed the friability test on Composition B and PBX-9502. These reciprocal tests were performed to compare the results of the alternate tests: friability versus Susan and Bullet Impact. Table 3 summarizes the results of this testing.

Examining the results in Table 3, we find that COMPOSITION B fails all of the tests, while PBX-9502 passes all of them. The French explosive B3103 does not give the same result for both the Susan Test and the Friability test--it passed the friability test and failed the Susan Test. The use of these tests as alternative procedures is currently under discussion and review.

The US representative to the North Atlantic Treaty Organization (NATO) Armament Committee AC/258 (Group of Experts on the Safety Aspects of Transportation and Storage of Military Ammunition and Explosives) proposed to reference the Test Series 7 protocol in NATO STANAG 4123. Work on revision 3 of this document with these changes is in progress. Based on the new terminology and test protocol adopted by the UN Committee and in NATO, the DDESB plans to change the name of "insensitive high explosive (IHE) articles" to "articles, EEI, and to replace the IHE screening tests with the UN Test Series 3 protocol and to adopt the Test Series 7 protocol in the place of the IHE test requirements. These changes will require a revision to the DOD Ammunition and Explosives Safety Standards (DOD 6055.9-STD), and the DOD Explosives Hazard Classification Procedures.

## CLASS/DIVISION 1.6 TEST SERIES

Materials which are candidate EIDS must pass the UN Test Series 3 protocol before they can be considered for UN Test Series 7 testing. Test Series 3, which is similar to the DOD Screening Tests for IHE, addresses the question: "Is the substance too hazardous for transport (in the form which it is tested)?" by determining the sensitivity of the substance to mechanical stimuli (both impact and friction) and to heat and flame.

After passing the Test Series 3 protocol, the EIDS candidate and the EEI article containing the EIDS candidate must pass the UN Test Series 7 protocol. This protocol consists of seven (7) substance tests and four (4) article tests. Test Series 7 addresses the question: "Is the item an extremely insensitive article?" Table 2 summarizes Test Series 7, including the pass/fail criteria. Details of the specific tests are given below.

## SUBSTANCE TESTS

Test 7(a) EIDS CAP TEST. **Objective:** Determine the shock sensitivity of an EIDS candidate to the shock from a standard detonator or blasting cap. **Approach:** The approach is the same as for UN Test 5(a). The EIDS candidate is placed in a cardboard tube (minimal confinement) with minimum dimensions of 80 mm (inside diameter), 160 mm length, and maximum wall thickness of 1.5 mm. Initiation is by a standard UN detonator (U.S. No. 8 Blasting Cap (or equivalent)) inserted coaxially into the top of the explosive to a depth equal to its length. The tube is placed on one of two witnesses which are positioned on a square steel plate of 25 mm thickness and 152 mm sides. The witnesses consist of either a lead cylinder with dimensions of 50.8 mm diameter and 101.6 mm length or a 1 mm thick 160 mm x 160 mm steel plate placed on a steel ring with dimensions 100 mm inner diameter, 50 mm length, and 3.5 mm wall thickness. Temperature control and/or cycling is required for those types of explosives known to have a temperature dependent cap sensitivity result. **Pass/Fail Criteria:** A detonation of the substance is indicated if either the lead cylinder is compressed from its initial length by an amount of 3.18 mm or greater or if the witness plate shows total penetration. A substance which detonates in any of three trials is termed "cap sensitive", is not an EIDS, and the result is a failure.

Test 7(b) EIDS GAP TEST. **Objective:** Defines the sensitivity of an EIDS candidate to a specified shock level (i.e., specified donor charge and gap spacing). **Approach:** The EIDS candidate is placed in a steel tube with dimensions 95 mm outside diameter (OD), 280 mm length, and 11 mm wall thickness. The steel tube is placed (with a 1.6 mm air gap) over a 200 x 200 x 20 mm steel witness plate. A donor charge and an intervening gap material are aligned above the EIDS candidate. To aid in alignment, the entire assembly is placed in a cardboard tube having dimensions of 97 mm ID and 443 mm length. The donor charge may either be 50/50 pentolite or 95/5 RDX/Wax at a density of 1600 kg/m<sup>3</sup>. The donor charge has dimensions 95 mm diameter and 95 mm length. The gap material is polymethylmethacrylate (PMMA) with dimensions of 95 mm diameter and 70 mm length. Initiation is by a standard UN detonator (U.S. No. 8 blasting cap (or equivalent)), positioned inside a 95 mm diameter by 25 mm long hole in a wooden block. The wood block is placed inside the cardboard tube on top of the donor charge. The explosives are to be at 25 ± 5 °C at the time of the test. **Pass/Fail Criteria:** A clean hole punched through the witness plate indicates a detonation. A substance which detonates in any of three (3) trials is not an EIDS and the result is a failure.

Test 7(c)(i) SUSAN IMPACT TEST. **Objective:** The test is designed to assess the degree of explosive reaction under conditions of high velocity impact. **Approach:** A 0.45 kg billet (dimensions 51 mm diameter by 102 mm length) of the EIDS candidate is placed in the Susan Projectile. The explosively-loaded Susan Projectile (5.4 kg total mass, 81.3 mm diameter by 220 mm long) is fired from an 81.3 mm smoothbore gun. The target is a 640 mm thick armor steel plate located 4.65 m from the muzzle. The projectile velocity should be adjusted to 333 m/s. A minimum of three overpressure measurements are taken at a range of 3.05 m from the target impact point along separate radial lines making angles of 20°, 38°, and 51° with the firing line. The test is repeated until at least 10 accurate pressure-time records are obtained from a minimum of five firings (at which the projectile velocity was 333 m/s). The maximum overpressure is determined from each airblast record. The average of the maximum pressures (minimum of 10 records) is recorded. **Pass/Fail Criteria:** If the average pressure is greater than or equal to 27 kPa, then the substance is not an EIDS and the result is a failure.

Test 7(c)(ii) and 7(d)(ii) FRIABILITY TEST. This test is an alternative to the Susan Impact Test and the Bullet Impact Test. **Objective:** This test is used to establish the tendency of a compact EIDS candidate to deteriorate dangerously under the effect of an impact. **Approach:** A bare cylindrical sample (18 mm diameter, length adjusted to give a mass of 9 grams) of the EIDS candidate is projected at a velocity of 150 m/s at a 20 mm thick steel target plate. The fragments of the EIDS candidate material are then recovered (the mass of these collected fragments should be at least 8.8 grams). The fragments are then burned in a 108 cm<sup>3</sup> manometric bomb. Ignition of the fragments in the bomb is obtained by a firing capsule consisting of a hot wire and 0.5 grams of black powder of average diameter 0.75 mm. The pressure-time curve produced by the burning is recorded, the derivative curve (dp/dt) is constructed, and the maximum value of dp/dt is recorded. **Pass/Fail Criteria:** If the average maximum dp/dt value obtained at an impact velocity of 150 m/s is greater than 15 MPa/ms, then the substance tested is not an EIDS and the result is a failure.

Test 7(d)(i) BULLET IMPACT TEST. **Objective:** The bullet impact test is used to evaluate a possible EIDS candidate to the kinetic energy transfer associated with the impact and penetration of a given energy source (a 12.7 mm projectile travelling at a velocity of 820 m/s). **Approach:** The EIDS sample is placed in a seamless steel pipe with dimensions 45 mm ID, 200 mm length, and 4 mm wall thickness (these are minimum dimensions). The pipe is closed with steel or cast iron end caps torqued to 204 N-m. A standard 12.7 mm armor-piercing bullet with a projectile mass of 0.046 kg is fired at the sample from a 12.7 mm gun at a velocity of 820 m/s. The sample is secured on a pedestal by a holding device capable of restraining the target from dislodgement by the bullet impact. Three tests each are conducted with the test article aligned with the long axis perpendicular and parallel to the projectile line of flight. These orientations result in impacts through the sides and ends of the pipes, respectively. Remains of the test container are collected. **Pass/Fail Criteria:** Complete fragmentation of the container indicates an explosion or detonation. A substance which explodes or detonates in any of six trials is not an EIDS and the result is a failure.

Test 7(e) EIDS EXTERNAL FIRE TEST. **Objective:** The external fire test is used to determine the reaction of an EIDS candidate to external fire when it is confined. **Approach:** The EIDS sample is placed in a seamless steel pipe with dimensions 45 mm ID, 200 mm length, and 4 mm wall thickness (these are minimum dimensions). The pipe is closed with steel or cast iron end caps torqued to 204 N-m. Five of these confined samples are stacked horizontally and banded together on a metal support stand (grid) at a height of between 0.5 and 1.0 meters above the fuel on the ground surface. Either firewood or liquid fuel can be used to produce a fire for a minimum of 30 minutes. Three tests with the five samples are conducted, or one test with all 15 test samples may be conducted. High speed and real time photographic coverage, blast overpressure measurements, post-shot photography of the samples, crater dimensions, and size/location documentation of the confining pipe fragments are required to determine the reaction severity. **Pass/Fail Criteria:** A substance which detonates or reacts violently with fragment (mass one gram or greater) throw of more than 15 m is not an EIDS and the result is a failure.

Test 7(f) EIDS SLOW COOK-OFF TEST. **Objective:** The purpose of this test is to determine the reaction of an EIDS candidate to a gradually increasing thermal environment and the temperature at which such reaction occurs. **Approach:** The EIDS sample is placed in a seamless steel pipe with dimensions 45 mm ID, 200 mm length, and 4 mm wall thickness (these are minimum dimensions). The pipe is closed with steel or cast iron end caps torqued to 204 N-m. The sample is placed in an oven which provides a controlled thermal environment over a temperature range of 40°C to 365°C and can increase the temperature of the surrounding oven atmosphere at a rate of 3.3°C per hour throughout the temperature range and ensure a uniform thermal environment for the test item. A means of relief should be provided for increased air pressure that is generated in the oven due to heating. The temperature of the air within the oven and the exterior surface of the confining pipe is to be recorded continuously or at a minimum of every 10

minutes. The test item is subjected to the gradually increasing air temperature at the prescribed rate until a reaction occurs. The temperature and the elapsed time are recorded. The test may begin with the test item preconditioned to 55°C below the anticipated reaction temperature. Three samples are subjected to this test. After each test, the pipe or any pipe fragments are recovered and examined for evidence of reaction. Such evidence may include the number and size of the recovered fragments as well as the distances the fragments are thrown. **Pass/Fail Criteria:** A substance which detonates or reacts violently (fragmentation of one or both end caps and fragmentation of the tube into more than three (3) pieces) is not an EIDS and the result is a failure.

## ARTICLE TESTS

**Test 7(g) CLASS/DIVISION 1.6 ARTICLE EXTERNAL FIRE TEST.** **Objective:** This test is used to determine the reaction of a possible 1.6 article to external fire as presented for transport. **Approach:** The approach is the same as for UN Test 6(c). Three or more candidate EEI articles in the condition and form in which they are offered for transport are stacked and banded together on a metal support stand (grid) at a height of between 0.5 and 1.0 meters above the fuel on the ground surface. Either firewood or liquid fuel can be used to produce a fire for a minimum of 30 minutes. A vertical aluminum witness sheet (2000 x 2000 x 2 mm) or equivalent is attached to posts in the ground in each of three quadrants at a distance of 4 m from the edge of the stack. The downwind quadrant is not used for witness screens. High speed and real time photographic coverage, blast overpressure measurements, radiometric measurements, post-shot photography of the samples, crater dimensions, and size/location documentation of test article fragments are required. The degree of reaction is determined by the blast/radiometric records, cratering, and size/location of article fragments. **Pass/Fail Criteria:** The article is not an EEI article and the result is a failure if any of the following events occur during the test: instantaneous/non-instantaneous explosion of total contents, perforation of any of the three witness screens, more than 10 metallic projections (each with a mass exceeding 25 grams) thrown more than 50 m from the edge of the stack, any metallic projections with mass exceeding 150 grams thrown more than 15 m from the edge of the stack, a fireball which extends more than 3 m from the flames of the fire, the irradiance of the burning product (scaled to 100 kg) exceeds 4 KW/m<sup>2</sup>, or fiery projections emanating from the articles are thrown more than 15 m from the edge of the stack. If any of the above reactions occur, the candidate EEI article is classified as Class/Division 1.1, 1.2, or 1.3, according to the above events.

**Table 7(h) CLASS/DIVISION 1.6 SLOW COOK-OFF TEST.** **Objective:** This test is used to determine an article's reaction to a gradually increasing thermal environment and the temperature at which a reaction occurs. **Approach:** A candidate EEI article in the condition and form in which it is offered for transport is placed in an oven which provides a controlled thermal environment over a 40°C to 365°C temperature range and can increase the temperature of the surrounding oven atmosphere at a rate of 3.3°C per hour throughout the temperature range and ensure a uniform thermal environment for the test item. A means of relief should be provided for increased air pressure that is generated in the oven due to heating. The temperature of the air within the oven and the exterior

surface of the confining pipe is to be recorded continuously or at a minimum of every 10 minutes. The article is subjected to the gradually increasing air temperature at the prescribed rate until a reaction occurs. The temperature and the elapsed time are recorded. The test may begin with the article preconditioned to 55°C below the anticipated reaction temperature. Two separate items are subjected to this test. After each test, the test article or its fragments are recovered and examined for evidence of reaction. Such evidence may include cratering and the number and size of recovered fragments, as well as the distance the fragments are thrown. **Pass/Fail Criteria:** The article is not an EEI article and the result is a failure if the reaction is more severe than burning. The energetic material may ignite and burn and the case may melt or weaken sufficiently to allow the mild release of combustion gases. Burning should be such that the case debris and package elements stay in the area of the test except for case closures which may be dislodged by the internal pressure and thrown not more than 15 m.

**Test 7(j) CLASS/DIVISION 1.6 ARTICLE BULLET IMPACT TEST.** **Objective:** This test is used to assess the response of a possible EEI article to the kinetic energy transfer associated with the impact and penetration of a given energy source. **Approach:** A candidate EEI article (complete) is secured in a holding device capable of restraining the item from dislodgement by projectiles. A 12.7 mm gun (or three guns) fires a three round burst (600 rounds/minute) of 12.7 mm armor-piercing ammunition with projectile mass of 0.046 kg at a velocity of 856 m/s to impact the candidate EEI article at a range of 3-20 m. The test is repeated in three different orientations. In the appropriate orientation(s), the striking point on the test article is selected so that the impacting rounds penetrate the most sensitive material(s), that is not separated from the main explosive charge by barriers or other safety devices. The test is documented by high speed and real time photographic coverage. The degree of reaction is determined by post-test inspection of the test films and the hardware. **Pass/Fail Criteria:** The article is not an EEI article and the result is a failure if any of the three bursts results in a detonation. Reactions of the article identified as no reaction, burning, or deflagration are considered acceptable (Passing).

**Test 7(k) CLASS/DIVISION 1.6 ARTICLE STACK TEST.** **Objective:** This test is used to determine if a candidate EEI article will detonate a similar item adjacent to it in the condition as presented for transport. **Approach:** The approach is the same as for UN Test 6(b), except that additional confinement is omitted. Three or more candidate EEI articles in the condition and form in which they are offered for transport are placed in a stack on a witness plate, such as a 3 mm thick mild steel sheet. One of the articles (donor) near the center of the stack is caused to function in the design mode. This test is conducted three times. Fragment data (size and number of acceptor article fragments), damage to the witness plate, and crater dimensions are used to determine whether any of the acceptors detonated. Blast data may also be used to determine if any of the acceptors detonated. **Pass/Fail Criteria:** The article is not an EEI article and the result is a failure if any of the three tests results in a detonation of an acceptor article. Evidence of a detonation includes but is not limited to: a crater at the test site appreciably larger than that for a single article, damage to the witness plate appreciably greater than that for a single article, or measurement of blast overpressure which significantly exceeds that from a single article.

The DDESB position on the implementation of this test is to conduct the first without confinement (Test 7(k)) and then conduct the next two tests with confinement (UN Test 6(b)). The unconfined test permits collection of airblast and fragmentation data without the attenuating effects of confinement; the confined tests subjects the acceptors to a more severe environment. Plans are to propose this modification to the UN Group of Experts at a future date.

## TEST RESULTS

Seven explosive substances either have been or are currently being examined under the Test Series 7 protocol. These materials are:

COMPOSITION B	60% RDX, 40% TNT, 1% WAX	cast material
PBX-9502	95% TATB, 5% KEL-F	pressed material
AFX-920	22%RDX, 33%HBNQ, 15% EDDN, 14% Aluminum, 15% binder, 1% other	cast material
AFX-930	32% RDX, 37% HBNQ, 15% aluminum, 9% binder, 7% plasticizer	cast material
AFX-931	32% RDX, 37% AP, 15% aluminum, 9% binder, 7% plasticizer	cast material
B3003	80% HMX, 20% energetic binder	cast material
B3103	51% HMX, 30% energetic binder, 19% aluminum	cast material
OCTORANE 86A	86% HMX, 14% inert binder	cast material

where HBNQ is high bulk density nitroguanadine and AP is ammonium perchlorate.

The DDESB funded the testing of COMPOSITION B and PBX-9502; AFX-920, AFX-930, and AFX-931 were developed and tested under Air Force contract. B3003, B3103, and OCTORANE 86A are French explosives tested by SNPE. The US conducted the Susan test on the three French materials, while the French performed the friability test on Composition B and PBX-9502. These reciprocal tests were performed to compare the results of the alternate tests: friability versus Susan and Bullet Impact. Table 3 summarizes the results of this testing.

Examining the results in Table 3, we find that COMPOSITION B fails all of the tests, while PBX-9502 passes all of them. The French explosive B3103 does not give the same result for both the Susan Test and the Friability test--it passed the friability test and failed the Susan Test. The use of these tests as alternative procedures is currently under discussion and review.

## IMPLICATIONS FOR QUANTITY-DISTANCE

As part of the protocol, the following definition and note concerning Class/Division 1.6 has been agreed to:

This division comprises articles which contain only extremely insensitive detonating substances (EIDS) and which demonstrate a negligible probability of accidental initiation or propagation. NOTE: The risk from articles of Division 1.6 is limited to the explosion of a single article.

This has been interpreted by the DDESB to imply that bulk EIDS are to be stored with the same quantity-distance requirements as Class/Division 1.3 materials. Class/Division 1.6 articles would use the same quantity-distance requirements as either Class/Division 1.2, 1.3, or 1.4, depending upon the type of storage, the type of packaging, and whether fuzed or non-fuzed.

## SUMMARY

A new class/division of energetic substances has been defined and incorporated into the United Nations classification procedures. The test protocol which must be followed in order to place articles into this class/division has been defined and approved by the United Nations Group of Experts on Explosives. These same procedures have been accepted within NATO (AC/258) for both transportation and storage. Several candidate substances have been tested and have passed the substance testing portion of the protocol. At least one classified article has passed an earlier version of the protocol as well.

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# TABLE 1 EXPANDED LARGE SCALE GAP CALIBRATION

(NOTE: Pressures in GPa)

GAP THICKNESS (mm)	INCREMENT (mm)				GAP THICKNESS (mm)	INCREMENT (mm)			
	" +0"	" +0.25"	" +0.50"	" +0.75"		" +0"	" +0.25"	" +0.50"	" +0.75"
9.00	10.96	10.89	10.81	10.74					
10.00	10.67	10.59	10.52	10.43					
11.00	10.35	10.28	10.21	10.14	56.00	4.83	4.81	4.79	4.78
12.00	10.06	9.99	9.92	9.85	57.00	4.76	4.74	4.72	4.70
13.00	9.79	9.73	9.66	9.61	58.00	4.68	4.66	4.64	4.62
14.00	9.55	9.49	9.43	9.37	59.00	4.60	4.58	4.56	4.53
15.00	9.31	9.26	9.20	9.15	60.00	4.51	4.49	4.46	4.44
16.00	9.10	9.04	8.99	8.93					
17.00	8.88	8.82	8.77	8.73	61.00	4.41	4.39	4.37	4.34
18.00	8.67	8.63	8.58	8.53	62.00	4.31	4.28	4.26	4.24
19.00	8.48	8.44	8.39	8.35	63.00	4.22	4.19	4.17	4.15
20.00	8.31	8.27	8.23	8.18	64.00	4.13	4.10	4.08	4.05
					65.00	4.02	4.00	3.97	3.94
21.00	8.14	8.11	8.07	8.03	66.00	3.91	3.88	3.86	3.83
22.00	8.00	7.96	7.93	7.89	67.00	3.80	3.78	3.75	3.72
23.00	7.86	7.83	7.79	7.76	68.00	3.70	3.68	3.66	3.63
24.00	7.72	7.69	7.66	7.62	69.00	3.61	3.59	3.57	3.55
25.00	7.58	7.55	7.51	7.48	70.00	3.53	3.51	3.48	3.46
26.00	7.44	7.40	7.37	7.33					
27.00	7.30	7.26	7.23	7.19	71.00	3.43	3.41	3.39	3.37
28.00	7.16	7.13	7.09	7.06	72.00	3.34	3.31	3.29	3.26
29.00	7.03	7.00	6.97	6.94	73.00	3.23	3.20	3.18	3.15
30.00	6.91	6.88	6.85	6.82	74.00	3.13	3.11	3.09	3.07
					75.00	3.05	3.03	3.01	3.00
31.00	6.79	6.77	6.74	6.71	76.00	2.98	2.96	2.95	2.93
32.00	6.68	6.65	6.62	6.59	77.00	2.92	2.90	2.89	2.87
33.00	6.57	6.54	6.51	6.48	78.00	2.85	2.83	2.80	2.78
34.00	6.45	6.42	6.40	6.37	79.00	2.76	2.74	2.71	2.69
35.00	6.34	6.32	6.29	6.27	80.00	2.66	2.64	2.61	2.59
36.00	6.25	6.23	6.20	6.18					
37.00	6.16	6.14	6.12	6.10	81.00	2.57	2.55	2.53	2.51
38.00	6.08	6.07	6.05	6.03	82.00	2.50	2.48	2.47	2.45
39.00	6.01	5.99	5.97	5.96	83.00	2.44	2.43	2.42	2.41
40.00	5.94	5.92	5.90	5.88	84.00	2.40	2.39	2.38	2.37
					85.00	2.36	2.35	2.34	2.33
41.00	5.86	5.83	5.81	5.79	86.00	2.31	2.30	2.29	2.27
42.00	5.77	5.75	5.73	5.71	87.00	2.26	2.25	2.23	2.22
43.00	5.69	5.67	5.66	5.64	88.00	2.20	2.19	2.18	2.16
44.00	5.62	5.61	5.59	5.57	89.00	2.15	2.14	2.13	2.11
45.00	5.56	5.54	5.53	5.51	90.00	2.10	2.09	2.08	2.07
46.00	5.49	5.47	5.45	5.44					
47.00	5.42	5.39	5.38	5.35	91.00	2.06	2.05	2.04	2.03
48.00	5.33	5.31	5.29	5.27	92.00	2.02	2.02	2.01	2.00
49.00	5.25	5.23	5.22	5.20	93.00	1.99	1.99	1.98	1.97
50.00	5.18	5.17	5.15	5.14	94.00	1.96	1.96	1.95	1.94
					95.00	1.94	1.93	1.93	1.92
51.00	5.13	5.11	5.10	5.09	96.00	1.91	1.91	1.90	1.89
52.00	5.08	5.07	5.06	5.04	97.00	1.88	1.87	1.86	1.84
53.00	5.03	5.02	5.00	4.99	98.00	1.82	1.81	1.79	1.76
54.00	4.98	4.96	4.94	4.93	99.00	1.73	1.69	1.66	1.62
55.00	4.91	4.89	4.87	4.85	100.00	1.57	1.52	1.46	

**TABLE 2 CLASS/DIVISION 1.6 TEST SERIES**

TEST NUMBER	NAME OF TEST	COUNTRY OF ORIGIN	FAILURE CRITERIA
<b>TESTS ON SUBSTANCES</b>			
7(a)	EIDS CAP TEST	Germany/US	Detonation of any sample
7(b)	EIDS GAP TEST	US	Detonation at gap of 70 mm
7(c) (i)	SUSAN TEST	US	$P > 27 \text{ kPa}$ @ $v = 333 \text{ m/s}$
7 (c)(ii)	FRIABILITY TEST	France	$dp/dt > 15 \text{ MPa/ms}$ for $v = 150 \text{ m/s}$
7(d) (i)	EIDS BULLET IMPACT TEST	US	Explosion/Detonation
7(d)(ii)	FRIABILITY TEST	France	$dp/dt > 15 \text{ MPa/ms}$ for $v = 150 \text{ m/s}$
7(e)	EIDS EXTERNAL FIRE TEST	UN	Detonation, fragment throw $> 15 \text{ m}$
7(f)	EIDS SLOW COOK-OFF TEST	US	Detonation, $> 3$ fragments
<b>TESTS ON ARTICLES</b>			
7(g)	1.6 ARTICLE EXTERNAL FIRE TEST	UN	C/D 1.1, 1.2, or 1.3 response
7(h)	1.6 ARTICLE SLOW COOK-OFF TEST	US	Reaction $>$ burning
7(j)	1.6 ARTICLE BULLET IMPACT TEST	US	Detonation
7(k)	1.6 ARTICLE STACK TEST	UN	Propagation

**TABLE 3 SUMMARY OF HAZARD CLASS/DIVISION 1.6 TEST RESULTS**

SUBSTANCE	TEST						
	EIDS CAP TEST	EIDS GAP TEST	SUSAN TEST	FRIABILITY TEST	EIDS BULLET IMPACT TEST	EIDS EXTERNAL FIRE TEST	EIDS SLOW COOK-OFF TEST
COMPOSITION B	+	+	+	+	+	+	+
PBX-9502	-	-	-	-	-	-	-
OCTORANE 86A			-	-	*		-
B3103			+	-	*		
B3003			+	+	*		+
AFX-920	-	-	-	*	-	-	-
AFX-930	-	-	-	*	-	-	-
AFX-931	-	-	-	*	-	-	-

NOTE: A "-" indicates that the substance passed the test

NOTE: A "+" indicates that the substance failed the test

NOTE: A "\*" indicates an alternate test (not required)

NOTE: A blank indicates data that is not available from the French